APPENDICES

APPENDIX A

Inspection & Maintenance Forms

Form 1
Inspection and Maintenance
Upper Tailings Pile
Embankments and Top Closure Surface

DATE/TIME:	WEATHER CONDITIONS:
PERSONNEL:	TEMPERATURE:

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
TOP CLOSURE SURFACE			
General condition			
Erosion			
Stability			
Vegetative growth			
Vegetative coverage			
Ponding			
Other			
RUNOFF CONTROL BERM			
General condition			
Erosion			
Stability			
Other			
EMBANKMENTS			
General condition			
Erosion			
Stability			
Sloughing			
Vegetative growth			
Vegetative coverage			
Seepage (visible)			
Toe Seep/Runoff Ditch			
Other			

Form 1 - UTP Embankments and Top Closure Surface - cont.

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
MISCELLANEOUS			
Damage to settlement monuments			
Damage to piezometer			
Barbed wire fence/gates			
Other			

Form 2
Inspection and Maintenance
Upper Tailings Pile
Runon Control Channel, Seepage Collection System and
East Fork Montezuma Creek Diversion

DATE/TIME:	WEATHER CONDITIONS:
PERSONNEL:	TEMPERATURE:

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
RUNON CONTROL CHANNEL			
General condition			
Erosion			
Channel riprap stability			
Geotextile			
Vegetative growth			
Ponding			
Sedimentation			
Drainage swale convergence			
Other			
EMBANKMENT			
General condition			
Stability			
Erosion			
Rock buttress movement			
Rock slope erosion			
Turf Reinforcement Mat			
Vegetative growth			
Other			

Form 2 - UTP Runon Control Channel, Seepage Collection System and E. Fork Montezuma Creek Diversion - cont.

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
ROCK SLOPE PROTECTION AND ROCK BUTTRESS			
General condition			
Rock displacement			
Undercutting			
Erosion			
Other			
SEDIMENT CONTROL STRUCTURES			
General condition			
Stability			
Erosion			
Debris			
Other			
SEEPAGE COLLECTION SYSTEM			
General condition/Ponding			
Seep area			
8" HDPE drain pipe inlet			
Concrete drain box			
4" ADS drain pipe outlet			
Overflow port			
Other			

Form 2 - UTP Runon Control Channel, Seepage Collection System and E. Fork Montezuma Creek Diversion - cont.

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
24" CMPs (2) AT FOREST SERVICE RD. 207			
General condition			
Inlet			
Sedimentation			
Outlet			
Other			
EAST FORK MONTEZUMA CREEK DIVERSION			
General condition			
Erosion of Banks			
Sedimentation			
Other			

Form 3
Inspection and Maintenance
Upper Tailings Pile
Runoff Controls and Toe Seep/Runoff Ditch

DATE/TIME:		**WEATHER CONDITIONS:**	
PERSONNEL:		**TEMPERATURE:**	
	CONDITION	**COMMENTS (Maintenance/Repair Needed)**	**MAINTENANCE PROCEDURE**
RUNOFF CONTROL CHUTE TO LOWER TAILINGS PILE			
General condition			
Erosion			
Sedimentation			
Ponding			
Placement of riprap			
Geotextile			
Turf Reinforcement Mat			
Vegetative growth			
Other			
SEEP COLLECTION DITCH TO TOP OF LTP EMBANKMENT			
General condition			
Erosion			
Sedimentation			
Turf Reinforcement Mat			
Vegetative growth			
Other			

Form 3 - UTP Runoff Controls and Toe Seep/Runoff Ditch - cont.

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
RUNOFF CONTROL CHANNEL (SOUTH)			
General condition			
Erosion			
Sedimentation			
Vegetative growth			
Diked deflection area (overtopping)			
Other			
18" CMP AT FOREST SERVICE RD. 207			
Inlet			
Sedimentation			
Outlet			
Other			
MISCELLANEOUS			
Barbed wire fence/gates			
Other			

Form 4
Inspection and Maintenance
Lower Tailings Pile
Embankments and Top Closure Surface

DATE/TIME:	WEATHER CONDITIONS:
PERSONNEL:	TEMPERATURE:

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
TOP CLOSURE SURFACE			
General condition			
Erosion			
Stability			
Vegetative growth			
Vegetative coverage			
Ponding			
Other			
RUNOFF CONTROL BERM			
General condition			
Erosion			
Stability			
Other			
EMBANKMENTS			
General condition			
Erosion			
Stability			
Sloughing			
Vegetative growth			
Vegetative coverage			
Seepage (visible)			
Toe Seep/Runoff Ditch			
Other			

Form 4 - LTP Embankments and Top Closure Surface - cont.

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
MISCELLANEOUS			
Damage to settlement monuments			
Damage to piezometer			
Barbed wire fence/gates			
Other			

Form 5
Inspection and Maintenance
Lower Tailings Pile
Runoff Controls and Runoff Outfall System to Montezuma Creek

DATE/TIME:	WEATHER CONDITIONS:
PERSONNEL:	TEMPERATURE:

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
RUNOFF CONTROL DITCH (NORTH) TO RUNOFF CHUTE			
CHANNEL			
General condition			
Erosion			
Sedimentation			
Vegetative growth			
Other			
24" CMP			
Inlet			
Sedimentation			
Outlet to runoff chute (erosion)			
Other			
RUNOFF CONTROL DITCH (SOUTH) TO CULVERT			
CHANNEL			
General condition			
Erosion			
Sedimentation			
Vegetative growth			
Other			
CULVERT UNDER FOREST SERVICE RD. 207			
Inlet			
Sedimentation			
Outlet			
Other			

Form 5
LTP Runoff Controls and Runoff Outfall System to Montezuma Creek - cont.

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
TOE DRAINAGE DITCH			
DITCH			
General condition			
Erosion			
Sedimentation			
Turf Reinforcement Mat			
Vegetative growth			
Other			
6" PVC PIPE AT TOE			
Inlet			
Sedimentation			
Outlet			
Other			
RUNOFF CONTROL CHUTE - TOP OF LTP EMBANKMENT TO DIVERSION DAM			
General condition			
Concrete cutoff wall			
Channel erosion			
Stability			
Sedimentation			
Placement of riprap			
Riprap stability			
Other			
DIVERSION DAM			
General condition			
Stability			
Rock displacement			
Undercutting			
Debris			
Geomembrane exposed?			
Other			

Form 5

LTP Runoff Controls and Runoff Outfall System to Montezuma Creek - cont.

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
HALF-ROUND 36" CMP			
Inlet			
Joints			
Erosion along edges			
Coating			
Outlet			
Other			
DISSIPATION AREA			
General condition			
Stability			
Rock displacement			
Undercutting			
Debris			
Other			
24" CMP UNDER FOREST SERVICE RD. 207			
Inlet			
Sedimentation			
Outlet			
Other			
CHANNEL TO MONTEZUMA CREEK			
General condition			
Erosion			
Sedimentation			
Placement of riprap			
Geotextile			
Vegetative growth			
Overland flow to Montezuma Creek			
Other			

Form 6
Inspection and Maintenance
Monitoring Systems at Tailings Piles

DATE/TIME:		WEATHER CONDITIONS:	
PERSONNEL:		TEMPERATURE:	
	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
Settlement Monuments			
Condition of Concrete Monuments			
Erosion or Material Displacement Around Monument			
UTP Piezometer Condition - Casing, Locking Top, Verticality Erosion			
LTP Piezometer Condition - Casing, Locking Top, Verticality Erosion			

Form 7
Inspection and Maintenance
Seep Control System
Seep Outfall Chute and Combined Seep Outfall

DATE/TIME:		**WEATHER CONDITIONS:**	
PERSONNEL:		**TEMPERATURE:**	
	CONDITION	**COMMENTS (Maintenance/Repair Needed)**	**MAINTENANCE PROCEDURE**
SEEP OUTFALL DITCH			
General condition			
Erosion			
Sedimentation			
Riprap stability			
Geotextile			
Vegetative growth			
Convergence with toe ditch flow below LTP			
Other			
12" ADS PIPE OUTFALL			
Inlet			
Sedimentation			
Other			

Form 8
Inspection and Maintenance
Seep Control System
Sedimentation Ponds and Infiltration Areas

ATE/TIME:		**WEATHER CONDITIONS:**	
ERSONNEL:		**TEMPERATURE:**	
	CONDITION	**COMMENTS (Maintenance/Repair Needed)**	**MAINTENANCE PROCEDURE**
SEDIMENTATION POND NO. 1			
General condition			
Erosion			
Sedimentation			
Embankments			
Vegetative growth			
Seepage			
Spillway			
Other			
SEDIMENTATION POND NO. 2			
General condition			
Erosion			
Sedimentation			
Embankments			
Vegetative growth			
Seepage			
Spillway			
Other			

Form 8 - Seep Control System - Sedimentation Ponds - cont.

	CONDITION	COMMENTS (Maintenance/Repair Needed)	MAINTENANCE PROCEDURE
SEDIMENTATION INFILTRATION POND NO. 3-4			
General condition			
Erosion			
Sedimentation			
Embankments			
Vegetative growth			
Seepage			
Inflow into Pond No. 4			
Overflow pipe, supports and trashrack			
Barbed wire fence/gates			
Other			
INFILTRATION AREA POND 6 (NORTH OF FOREST SERVICE RD. 268)			
General condition			
Pipeline from Pond 3-4 to Pond 6			
Inflow ditch to Pond 6			
Dike Adjacent to Infiltration Trench			
Top of Infiltration Trench			
Erosion			
Ponding (water depth)			
Discharge from Pond 6			
Vegetative growth			
Other			

Form 9
Inspection and Maintenance
Colluvial Borrow Area

DATE/TIME:		**WEATHER CONDITIONS:**	
PERSONNEL:		**TEMPERATURE:**	
	CONDITION	**COMMENTS (Maintenance/Repair Needed)**	**MAINTENANCE PROCEDURE**
Borrow Area			
General condition			
Erosion			
Stability			
Vegetative growth			
Ponding			
Other			
24" CMP CULVERT AT FOREST SERVICE RD. 268			
General condition			
Inlet			
Sedimentation			
Outlet			
Other			

APPENDIX B

Monitoring Records

RECORD 1
MONITORING RECORDS
SETTLEMENT MONUMENTS

DATE/TIME:	**WEATHER CONDITIONS:**		
PERSONNEL:	**TEMPERATURE:**		
SETTLEMENT MEASUREMENTS	**NORTHING**	**EASTING**	**ELEVATION**
UPPER TAILINGS PILE			
Settlement Monument SM-1			(ft, AMSL)
Settlement Monument SM-2			(ft, AMSL)
Settlement Monument SM-3			(ft, AMSL)
LOWER TAILINGS PILE			
Settlement Monument SM-4			(ft, AMSL)
Settlement Monument SM-5			(ft, AMSL)

Note: Indicate any significant movement (>2") from previous measurement.

RECORD 2
MONITORING RECORDS
PIEZOMETERS

DATE/TIME:	**WEATHER CONDITIONS:**
PERSONNEL:	**TEMPERATURE:**
SETTLEMENT MEASUREMENTS	
UPPER TAILINGS PILE	
UTP Piezometer: depth to water	(ft)
UTP Piezometer: water elevation	(ft, AMSL)
LOWER TAILINGS PILE	
LTP Piezometer: depth to water	(ft)
LTP Piezometer: water elevation	(ft, AMSL)

Note: Indicate any significant rise in water levels (>3') from previous measurement.

RECORD 3
SEEP WATER MANAGEMENT SYSTEM

GROUNDWATER MONITORING WELL

DATE/TIME:	**WEATHER CONDITIONS:**
PERSONNEL:	**TEMPERATURE:**

GROUNDWATER MONITORING WELL BELOW SEEP MANAGEMENT SYSTEM		
Depth to Water		(ft)
Water Elevation		(ft, AMSL)
SAMPLING MEASUREMENTS		
Sampling Method		(bailer or peristaltic pump)
Sampling Depth		(ft.)
Temperature		(°C)
pH		(std. units)
Specific Conductance		(Minhos/cm)
Remarks:		
SAMPLING INVENTORY		
Bottles Collected (No. & Vol.; glass or plastic)		
Filtration		(y/n)
Preservation Type		
Remarks:		
QUALITY ASSURANCE		
Methods (Cleaning & Sampling)		
Instruments		
Remarks:		

Note: Perform groundwater monitoring and sampling in accordance with SOP No. 11 (Appendix C).

SURFACE WATER SAMPLING RECORD-3A

SAMPLE NUMBER:

Project No:________________ Project Name:________________________________ Page _____ of: _______

Sampled by ____ Date: __________________

Weather (@ sampling): ________________________ Weather (past 48 hrs.) ________________________

Sampling Location (i.d., description): ____

Water Body (describe type, flow):

QUALITY ASSURANCE

METHODS (describe):

Cleaning Equipment: ____

Sampling:____

INSTRUMENTS (indicate make, model, i.d.):

Flow Measurement: ________________________ Thermometer: ________________________

pH Meter: ________________________ Field Calibration: ________________________

Conductivity Meter: ________________________ Field Calibration: ________________________

Filtration: Other:

SAMPLING MEASUREMENTS

Time	Sampling Depth (ft.)	Water Quality Data				Appearance		Remarks (debris, sheen, etc.)
		Temp. (°C)	pH	Specific Conductance (µmhos/cm)		Color	Turbidity & Sediment	
				@ Field Temp.	@ 25° C.			

Flow @ Sampling Point (units): Total Depth @ Sampling Point (Ft.):

SAMPLE INVENTORY

Bottles Collected				Filtration (Y/N)	Preservation (type)	Remarks (quality control sample, other)
Time	Volume	Composition (glass, plastic)	Quantity			

SAMPLING LOCATION MAP

(ref. permanent landmarks, indicate scale, approx. North, flow)

MFG, INC.
4900 PEARL EAST CIRCLE
SUITE 300W
BOULDER, CO 80301
(303) 447-1823

Note: This form to be completed for all sampling points S1, S2 and S3. Perform water quality sampling in accordance with MFG SOP No. 12 (Appendix C) and water flow rate measurements in accordance with SOP No. 15 (Appendix C), as applicable.

APPENDIX C

Standard Operating Procedures

STANDARD OPERATING PROCEDURE FOR VEGETATION COVER MEASUREMENT

1.0 INTRODUCTION

This Standard Operating Procedure (SOP) describes the protocols to be followed while conducting measurements of vegetative cover. The procedures presented herein are intended to be of general use. As the site work progresses, and if warranted, appropriate revisions will be made and approved in writing by the Project Manager.

2.0 VEGETATION COVER MEASUREMENTS

2.1 SITE LAYOUT

This section applies to the general layout and adaptation of the actual site for conducting vegetation cover measurements. Vegetation cover measurements will be conducted only on areas of interest larger than ¼ acre. The outline of the barrier or revegetation area identified for cover measurements will be mapped and the area divided into ½-acre subareas. One measurement transect will be randomly located in the approximate center of each subarea.

2.2 DATA COLLECTION

The vegetative cover will be determined using the point-intercept method (Bonham, C.D. 1989. Measurements for Terrestrial Vegetation. John Wiley & Sons, NY. 338 p.). The basic premise of the point-intercept method is that plant cover within a given area can be determined by recording the number of points that actually hit plants if an infinite number of points are placed in a two-dimensional area. The point-intercept method consists of extending a transect line a predetermined distance through a vegetated area judged to represent the given community type or seeded area. The type of material (e.g., vegetation biomass, soil, rock, etc.) is recorded at each assigned point, or intercept, along the transect line. The total number of vegetative "hits" is divided by the total possible hits to obtain the percent vegetative cover.

Vegetative cover measurements will be taken using 2 transects per acre in revegetated areas. Each transect will be 50 meters long and will be randomly placed. The type of material observed under each 1 meter interval of the transect will be recorded. Thus 100 points per acre will be recorded.

Revegetation success standards shall be judged by the percent ground cover of the existing vegetation and litter, and by the percent of species represented by the original seed mixture. Ground cover is defined as the area of ground surface covered by the combination of the aerial portion of the vegetation plus the litter that is produced naturally by the existing on-site vegetation. This measurement excludes rock surface areas. The combination of plant canopy cover and litter shall be at least 70% of that of a reference area of adjacent undisturbed native vegetation.

Vegetation quality criteria will include the abundance of species occurrence on the site, vegetation condition, and the trend of the vegetative community. Species abundance describes the number of times a particular species is encountered in a given number of sample points, or the number of hits in the point-intercept line transect, and is expressed as a percentage. Vegetation condition describes the general overall appearance of the health of the plants and will be expressed as good, fair, or poor. Trend indicates the trajectory of the vegetative community and will be expressed as increasing, static, or decreasing. Vegetation quality criteria shall be proclaimed successful if at least 50% of the species counted in plant canopy cover measurements are from the original seed mixture, the condition is fair or good, and the trend is static or increasing. Additionally, not more than 5% of the plant canopy cover shall be represented by noxious weeds.

3.0 DOCUMENTATION

3.1 DAILY FIELD RECORD

An experienced field representative will document the activities of each day of field work chronologically in accordance with the procedures contained in the QA/QC Plan. Entries in the field log book will include:

A. Mapped outline of the barrier/revegetation area of interest (larger than ¼-acre), including ½-acre divisions;

B. Location and length of each transect, along with sampling interval length;

C. General observations of plant cover throughout the barrier/revegetation area, relative to the transect sampling area; and

D. Percent cover calculation for the barrier/revegetation area.

3.2 PERCENT COVER CALCULATIONS

Percent vegetative cover will be determined for each barrier/revegetation area by the following procedure:

A. For each transect, sum the vegetative "hits" to develop a total number of hits per transect. Also, sum the number of observations (i.e., potential hits) per transect.

B. For all transects combined, divide the grand total of hits by the grand total of observations (potential hits) and multiply by 100 to obtain the percent vegetative cover for the barrier/revegetation area.

MFG, Inc.

STANDARD OPERATING PROCEDURE No. 11

WATER LEVEL, IMMISCIBLE LAYER AND WELL DEPTH MEASUREMENT

1.0 SCOPE AND APPLICABILTIY

This Standard Operating Procedure (SOP) describes the protocol to be followed during measurement of water levels, immiscible layer levels and depths of monitoring wells and piezometers. The procedures presented herein are intended to be general in nature and, as the work progresses and when warranted, appropriate revisions may be made when approved in writing by the MFG Project Manager.

2.0 PROCEDURES

Prior to performing water level, immiscible layer and well depth measurements, the construction details and previous measurements for each well or piezometer shall be reviewed by the MFG field geologist so any anomalous measurements may be identified. Well construction details and previous measurements shall be available in the field for review.

In general, water-level and immiscible-layer depth measurements shall be performed before groundwater is removed from the well by purging or sampling.

2.1 Equipment

Equipment that may be necessary to perform measurements (depending on measurements to be performed):

- Well/piezometer construction details
- Water-level meter
- Water Level Monitoring Record Sheet

- Inteface probe/gas-finding paste/water-finding paste
- Weighted steel surveyor's tape measuring to the nearest 1/10 foot.

2.2 Measuring Point

A measuring point (MP) shall be selected and marked for each monitoring well and piezometer in which water level measurements will be made. Generally, the MP will be the top of the well casing on the north side. The MP will be permanently marked using an indelible marker or a notch cut into the PVC casing. When the top-of-casing elevation of a monitoring well or piezometer is surveyed, the licensed surveyor shall measure the MP elevation and reference this measurement to an appropriate datum (such as feet above mean sea level).

2.3 Water Level Measurements

When water levels are measured to describe the groundwater potentionmetric surface, the water level will be measured prior to purging. All water level measurements will be recorded to the nearest hundredth of one foot. Note the instrument used for each measurement on the Water Level Monitoring Record (Figure SOP-11-1). The measurement procedures to be followed when an immiscible layer is present or suspected in a well are discussed in Section 2.3. Water levels are measured using the electric probe method, as discussed below.

An electric probe consists of a contact electrode attached to the end of an insulated electric cable, and a reel which houses an ammeter, a buzzer, or other closed circuit indicator. The indicator shows a closed circuit and flow of current when the electrode touches the water surface. The electric probes used shall be calibrated periodically by comparing the depth-to-water readings between the electric probe and a steel surveyors' tape. Calibration procedures are discussed in Part B of this section.

The procedure for measuring water levels with an electric probe is as follows:

1. Switch on.

2. Lower the electric cable into the well until the ammeter or buzzer indicates a closed circuit. Raise and lower the electric cable slightly until the shortest length of cable that gives the maximum response on the indicator is found.

3. With the cable in this fixed position, note the depth to water from the Measuring Point (MP).

4. Repeat as necessary until at least two identical duplicate measurements are obtained.

Calibration of the electric probe will be checked at regular intervals as part of regular maintenance measuring the position of the electrode to check that the calibration marks on the electric probe correspond to those on the steel surveyors tape.

2.4 Immiscible Layer Measurement and Sampling

2.4.1 Immiscible Layer Measurement

The thickness of non-aqueous phase liquid (NAPL) in a well may be measured by using (A) an interface probe, (B) gas-finding paste with a water-level meter or (C) water-finding paste with a steel surveyor's tape.

A. Use an interface probe in a similar fashion as an electric water-level probe. An interface probe may be used to measure the thickness of both a light-phase NAPL (LNAPL) and a dense-phase NAPL (sinker). Measure a light-phase NAPL prior to measuring a dense-phase NAPL.

B. Gasoline gauging paste is used for measuring LNAPL (floaters) only. Gasoline gauging paste can be used to detect petroleum hydrocarbons and other LNAPL chemicals. Using a graduated electronic water-level probe, apply a thin layer of gasoline gauging paste (Kolor-kut brand or equivalent) to the amount of tape greater than the anticipated LNAPL thickness. Make a depth to water measurement; probe buzzer/light will activate when it contacts the water (not the LNAPL). Record the depth to water from the MP then quickly reel up the tape. Record level of the LNAPL on the tape by noting where the gasoline gauging paste has changed color. This level will be the thickness of the LNAPL layer.

C. Water-finding paste is used only for LNAPLs . Using a steel surveyor's tape coated with chalk on the bottom foot, take a depth to "liquid" measurement from the measuring point (MP) of the well, as described in Section 2.2. Record the depth to "liquid" measurement. Clean and dry the steel tape and recoat the bottom calibrated foot with fresh chalk. Along one edge of the bottom calibrated foot of the steel tape, apply a thin layer of the yellow water-finding paste (Kolor-Kut brand or equivalent). Take another "depth to liquid" measurement from the MP of the well. Upon retrieving the steel tape, quickly note the depth to "liquid" marked by the wet/dry chalk interface along one edge, and the depth to water marked by the yellow/red paste interface along the other edge. Record the chalk measurement as the depth to "liquid" and the paste measurement as the depth to water. The thickness of the NAPL is the difference between these two measurements. If the two readings are identical, then there is no measurable NAPL in the well.

Record the thickness of the NAPL in the "Remarks" column of the Water Level Monitoring Record (Figure SOP-11-1). To calculate the corrected water level elevation in the presence of LNAPL, use the worksheet provided as Figure SOP-11-2.

If a light-phase NAPL (floater) is not detected using the water-finding paste, gasoline gauging paste or interface probe, but the presence of light-phase NAPL is suspected, the presence of a very thin layer or sheen (too thin to be measured) may also be checked using a bottom-filling transparent bailer. The presence of a light-phase layer is checked by lowering the bailer into the well. Care must be taken to <u>not</u> completely submerge the bailer. Retrieve the bailer and visually examine the air/liquid interface for the presence of an immiscible light-phase layer or sheen. Note that the transparent bailer is not to be used to measure the thickness of light-phase NAPL in a well.

The presence of a dense-phase NAPL (sinker) may also be checked next by lowering the bailer to the base of the well. Retrieve the bailer and visually examine for the presence of an immiscible, dense-phase layer. Note that the transparent bailer is not to be used to measure the thickness of dense-phase NAPL in a well.

2.4.2 Immiscible Layer Sampling

Samples of immiscible layers may be obtained with a bailer (A) or a peristaltic pump (B), if the well is shallow (i.e., depths of about 20 feet or less, depending upon the liquid).

A. Bailer Method -- A appropriate sampling bailer with a ball check valve is submerged to the desired sample depth, either directly or by suspending the bailer on a rope from a pole.

B. Peristaltic Pump Method -- The sample is collected through a section of clean, flexible Tygon (polyvinyl chloride) tubing which will not be reused. The tubing intake will be secured manually or by attaching weights. This procedure may be modified to collect the sample through a Teflon tube into a sample flask by running the pump on a vacuum.

Sample containers prepared specifically for the required analyses by the analytical laboratory or their supplier will be used for sample collection. To collect a sample in a volatile organic analysis (VOA) vial, remove the cap with Teflon-lined septum, then fill slowly (avoiding agitation) until a miniscus of NAPL (held by surface tension) extends above the top of the vial. Carefully replace the cap, then turn the vial upside down and tap gently while checking to ensure that no headspace (air bubbles) is present in the vial.

2.4.3 Sample Handling

Care should be taken to thoroughly clean the outside of the sample bottles that contain the immiscible liquids. To avoid potential cross-contamination, these samples will be kept in a designated ice chest, separate from other groundwater samples. Equipment used in immiscible layer measurement and sampling must be thoroughly decontaminated in accordance with the procedure described in Section 4.0 of this SOP. Samples will be handled in accordance with the procedures described in the MFG SOP entitled SAMPLE CUSTODY.

2.5 Well Depth Measurements

The total depth of a well shall be measured by sounding with a weighted steel surveyors' tape or other steel or fiberglass measuring tape, weighted as needed. For shallow wells, the electronic water-level probe may also be used as a measuring device. Procedures to be followed are specified below.

A. For calibration, measure the distance between the zero mark on the end of the measuring tape and the bottom of the weight to the nearest 1/10 foot at the beginning of each well depth measurement activity day, and whenever the apparatus is altered.

B. Lower a weighted tape into the well until the tape becomes slack or there is a noticeable decrease in weight, which indicates the bottom of the well. Care should be taken to lower the tape slowly to avoid damage to the bottom of the well by the weight. Raise the tape slowly until it just becomes taut, and with the tape in this fixed position, note the tape reading opposite the Measuring Point to the nearest 1/10 foot. Add the values from the distance from the end of the tape to the end of the weight together, round this number to nearest 1/10 foot, and record the resulting value as "well depth below MP" in the "Remarks" column of the Water Level Monitoring Record form.

2.6 DOCUMENTATION AND RECORDS MANAGEMENT

Water levels observed in wells selected for the groundwater level monitoring program will be tabulated on a Water Level Monitoring Record form during each monitoring period (Figure SOP-11-1). The date and time of each measurement will also be recorded on the Water Level Monitoring Record. All water level measurements shall be recorded to the nearest 1/100 foot, and all depth measurements shall be noted to the nearest 1/10 foot.

Water level data will be recorded as feet below measuring point so that water level elevations may be calculated from the depth-to-water measurement (from measuring point) and the surveyed elevation of the measuring point at each well or piezometer.

Well depth measurements may be recorded in the "Remarks" column of the Water Level Monitoring Record.

If free product is encountered during water level measurement, the measured thickness or observation shall be recorded in the "Remarks" column. Each form or, as appropriate, individual measurement data, shall be signed to indicate the originator. If LNAPL is encountered, the corrected water level elevation may be calculated using the procedures included on Figure SOP-11-2.

3.0 QUALITY CONTROL

3.1 Equipment Decontamination/Cleaning

Steel surveyors' tapes, electric well probes, and other measuring tapes shall be cleaned prior to use and after measurements in each well are completed. Cleaning shall be accomplished by either (1) washing with a laboratory-grade detergent/water solution, rinsing with clean, potable, municipal water, then rinsing with distilled or deionized water, or (2) steam cleaning followed by rinsing with distilled or deionized water. An acid rinse (0.1 N HCl) or solvent rinse (i.e., hexane or methanol) may be used to supplement these cleaning steps if tarry or oily deposits are encountered. The acid or solvent rinse will be followed by thoroughly rinsing with municipal water and then with distilled or deionized water. After cleaning, equipment will be packaged and sealed in plastic bags or other appropriate containers to minimize contact with dust or other contaminants.

3.2 Technical and Records Reviews

The project manager or designated QA reviewer will check and verify that documentation has been completed and filed per this procedure.

In addition, all calculations of water-level elevations and NAPL correction to water-level elevations must be reviewed before they are submitted to the project file and used to describe site conditions. The calculation review should be performed by technical personnel familiar with this procedure. Evidence of the completed review and any necessary corrections to calculations should also be submitted to the project file.

MFG, Inc.

STANDARD OPERATING PROCEDURE No. 12

WATER QUALITY SAMPLING

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the protocol to be followed during sampling of surface water, groundwater, stormwater or waste water. Note that the protocol for collection of non-aqueous phase liquid (NAPL) samples from monitoring wells is provided in the MFG, Inc. (MFG) SOP entitled WATER LEVEL, IMMISCIBLE LAYER AND WELL DEPTH MEASUREMENT. The procedures presented herein are intended to be general in nature. Appropriate revisions may be made to accommodate site-specific conditions or project-specific protocols when they are approved in writing by the MFG Project Manager or detailed in a project work plan, sampling plan or quality assurance project plan.

2.0 PROCEDURES

2.1 Groundwater Sample Collection

Individual samples from wells will be collected as follows:

A. The depth to water, the thickness or presence of a Non-Aqueous Phase Liquid (NAPL) in a well and the total depth will be measured using the procedures discussed in the MFG SOP entitled WATER LEVEL, IMMISCIBLE LAYER AND WELL DEPTH MEASUREMENT.

B. A positive displacement pump, submersible pump, and/or bailer will be used for removing the groundwater in the monitoring wells (purging). Equipment used for purging and sampling may be permanently installed (dedicated) in the monitoring wells. Care must be taken that bailers and/or tubing are constructed from materials that will not affect the sample analyses.

C. Wells will be pumped or bailed at least until the volume of water removed is equal to three casing volumes (volume of standing water in the well based upon total depth of well, the depth to water, and the well casing diameter). The purge rate must not reach a point where the recharge water is entering the well in an agitated manner. To assure that the water samples are representative of the water-yielding zone, periodic measurements of the temperature, pH, and specific conductance will be made. The sample will be collected only when the temperature, pH and specific conductance reach a relatively constant value (see Section 2.8) or after five well volumes have been removed. If the yield of the well is low such that it can be bailed or pumped dry, then the recharged groundwater in the well will be considered representative regardless of the number of casing volumes of groundwater removed, since all standing water in the well has been replaced by recharge from the water-yielding zone. If a well is purged dry, the well can be sampled upon 90% recovery or after two hours, whichever occurs first.

D. For specific projects, a low-flow purge method or "micopurge" method may be used for sample collection. Wells will be purged at a low pumping rate to minimize agitation of water in the well and minimize drawdown. The goal is to limit drawdown in the well to less than 10 percent of the length of the saturated well screen. If the initial water level is above the top of the screen, then the goal is to limit drawdown due to purging so that the water level in the well does not drop below the top of the screened interval. Wells will be purged by pumping water at a rate less than 250 mL per minute. Bailers will not be used for purging of sampling wells.

E. A sample drawn from plumbing on municipal or domestic wells will be taken at the access valve closest to the well and upstream of any water softening or chlorination input.

F. Prior to collecting samples from a well, a clean plastic apron will be placed adjacent to or around the well to prevent equipment and sample containers from coming into contact with surface materials. Alternatively, a clean field table may be set up near the well. If used, the table will be cleaned (Section 6.0) before and after use at each well.

G. Sample containers prepared specifically for the required analyses by the analytical laboratory or their supplier will be used for sample collection. Samples for volatile organic compound analyses will be collected first. To collect a sample in a volatile organic analysis (VOA) vial, remove the cap with Teflon-lined septum, then fill slowly (avoiding agitation) until a miniscus of sample water (held by surface tension) extends above the top of the vial. Carefully replace the cap, then turn the vial upside down and tap gently while checking to ensure that no headspace (air bubbles) is present in the vial.

Other glass sample bottles for semi- and non-volatile analyses should be filled to near the top. To account for slight expansion due to temperature changes, leave headspace approximately equivalent to the volume of liquid which would fill the bottle's cap. Plastic sample bottles should be filled completely. Splashing of the water in the sample container and exposure to the atmosphere shall be minimized during sampling. The container cap will be screwed on tightly immediately after filling the sample container. Sample filtration, if necessary, is discussed in Section 2.4 of this SOP.

Sample bottles that do not contain preservative should be rinsed with the sample water prior to filling.

H. Where more than one well within a specific field or site is to be sampled, the sampling sequence should begin with the well having the lowest suspected level of contamination. Successive samples should be obtained from wells with increasing suspected contamination. If the relative degree of suspected contamination at each well cannot be reasonably assumed, sampling should proceed from the perimeter of the site towards the center of the site. The sampling sequence should be arranged such that wells are sampled in order of increasing proximity to the suspected source of contamination, starting from the wells up-gradient of the suspected source.

I. Sampling activity for each monitoring well will be recorded on a Groundwater Sampling Record (example attached).

2.2 Surface Water Sample Collection

Individual samples from surface water sampling stations will be collected as follows:

A. Where multiple sampling stations exist along a moving water source (i.e., a creek or drainage channel), the downstream station will be sampled first. A moving water sample will be taken from the portion of the water with maximum flow at any given sampling station unless otherwise specified. If the sampling point is inaccessible from shore, the sampling personnel will enter the water from a point downstream of the sampling point, taking care not to disturb the water.

B. A standing water sample will be taken at a point in the body of water at least three feet from the shore, if possible, or unless otherwise specified.

C. A surface water sample will be collected according to one of the following, or similar, techniques.

   1. Direct Method -- Sample bottle is inverted, submerged to the specified depth, turned upright, removed from the water, and then capped. Add preservative, if any, after sample collection.

   2. Dipper Method -- Sample bottle or container attached to a pole is dipped in the water, raised above the water, and then capped (if actual sample bottle used).

3. Bailer Method -- A appropriate sampling bailer with a ball check valve is submerged to the desired sample depth, either directly or by suspending the bailer on a rope from a pole.

4. Syringe Method (for very shallow water) -- A disposable plastic filtering syringe may be used to collect very shallow surface water without disturbing the sediment. The syringe will be disposed of after each use.

5. Peristaltic Pump Method -- The sample is collected through a section of new, clean, flexible Tygon (polyvinylchloride) tubing. The tubing intake will be secured manually or by attaching weights. This procedure may be modified to collect the sample through a Teflon tube into a sample flask by running the pump on a vacuum.

D. The first collected water will be used to rinse the sampling equipment. Sample bottles that do not contain preservative should be rinsed with the sample water prior to filling. Subsequent water collected will be used to fill the analytical sample bottles until all bottles are filled. Field measurement of parameters will be taken once for each sampling station. Field parameters (pH, specific conductance, temperature, odor, turbidity, and/or sediment) will be measured from a separate container (instruments will not contact the analytical samples).

E. A stake or pole identifying the sampling station should be placed at or near the sampling station for future identification of the location. MFG personnel will record a brief description of the stake or pole location in relation to permanent landmarks, and the sampling location in relation to the stake or pole (example: stake is approximately 100 feet west along Markley Creek from Somersville Road, on north-side shore. Sampling point is 25 feet south of stake, in middle of Markley Creek). MFG personnel will include a sketch map of the sampling station in the Surface Water Sampling Record (example attached).

2.3 Sample Filtration

When required, a field-filtered water sample will be collected using a disposable, in-line 0.45 μm filter. The water sample will be pumped through the filter using a peristaltic pump and a section of Tygon (polyvinylchloride) tubing or other appropriate method. An aliquot of approximately 100 ml of sample will be run through the tubing and filter prior to collection into the sampling containers. Both the filter and tubing will be disposed of between samples.

2.4 Sample Containers and Volumes

The sample containers will be appropriate to the analytical method and will be obtained from the water analysis laboratory or other approved source. Different containers will be required for specific groups of analytes in accordance with U.S. EPA Methods, project-specific requirements, and/or other local jurisdictional guidance. The MFG sampler will confirm with the laboratory performing the analyses that appropriate bottleware and preservatives are used and ensure that a sufficient volume of sample is collected.

2.5 Sample Labeling

Sample containers will be labeled with self-adhesive tags. Each sample will be labeled with the following information using waterproof ink.

A. Project identification;

B. Sample identification;

C. Date and time samples were obtained;

D. Requested analyses and method;

E. Treatment (preservative added, filtered, etc.); and

F. Initials of sample collector(s).

2.6 Sample Preservation and Storage

If required by the project or analytical method, water samples submitted for chemical analysis will be stored at 4°C in ice-cooled, insulated containers immediately after collection. Preservation and storage methods depend on the chemical constituents to be analyzed and should be discussed with the water analysis laboratory prior to sample collection. EPA and/or other local jurisdictional requirements and/or the requirements of a project-specific plan (e.g., sampling and analysis plan, work plan, quality assurance project plan, etc.) shall be adhered to in preservation and storage of water samples.

2.7 Sample Custody

Samples shall be handled and transported according to the sample custody procedures discussed in the MFG SOP entitled SAMPLE CUSTODY. The sample collector shall document each sample on the Chain-of-Custody and Request for Analysis form (Figure SOP-2-1).

2.8 Field Measurements

Specific conductance, pH, and temperature measurements may be performed on water samples at the time of sample collection. Data obtained from these (or other) field water quality measurements will be recorded on the appropriate sampling records. Separate aliquots of water shall be used to make field measurements (i.e., sample containers for laboratory analysis shall not be reopened).

For groundwater samples, field measurement intervals will be calculated based upon the casing volume of the monitoring well so that at least four readings will be taken during the course of purging the target volume from the well (at least three casing volumes). Note that the target volume criteria does not apply if the well is purged dry. If the parameters have not stabilized after the target volume is removed from the well, field measurements and purging will continue until two consecutive readings have stabilized to within the following limits or until five casing volumes have been removed:

- Specific conductance+/-10%
- pH +/-0.05 pH units
- temperature+/-1EC

For surface water sampling, the parameters will be measured once and recorded.

2.8.1 Temperature Measurement

Temperature will be measured directly from the water source or from a separate sample aliquot. Temperature measurements will be made with a mercury-filled thermometer, bimetallic-element thermometer, or electronic thermistor. All measurements will be recorded in degrees Celsius (°C).

2.8.2 pH Measurement

A pH measurement will be made by dipping the probe directly into the water source or into a separate sample aliquot. Prior to measurement, the container in which the field parameter sample will be collected will be acclimated to the approximate temperature of the sample. This can be accomplished by immersing the container in water removed from a well during the purging process. The pH measurement will be made as soon as possible after collection of the field parameter sample, preferably within a few minutes, using a pH electrode. The value displayed on the calibrated instrument will be recorded after the reading has stabilized. If the value falls outside of the calibrated range, then the pH meter will be recalibrated using the appropriate buffer solutions.

2.8.3 Specific Conductance Measurement

Specific conductance will be measured by dipping the probe directly into the water source or into a separate sample aliquot. The probe must be immersed to the manufacturer's recommended depth. Specific conductance will be reported in micromhos/cm at 25°C. If the meter is not equipped with an automatic temperature compensation function, then the field value will be adjusted at a later time using the temperature data and the following formula:

$$SC_{25} = SC_T / [1 + \{(T - 25) \times 0.025\}]$$

where: SC_{25} = specific conductance at 25°C
SC_T = specific conductance measured at temperature T (°C)
T = sample temperature (°C)

The value displayed on the calibrated instrument will be recorded after the reading has stabilized. If the value falls outside of the calibrated "range" set by the range dial on the instrument, then the range setting will be changed to a position which gives maximum definition. If the specific conductance value falls outside of the calibrated range of the conductivity standard solution, then the instrument will be recalibrated using the appropriate standard prior to measurement.

2.8.4 Equipment Calibration

Equipment used to measure field parameters will be calibrated by MFG personnel according to manufacturer's instructions. Calibration checks will be performed at least once prior to and at least once following each day of instrument use in the field and the results will be documented on the Sampling Record for each sampling station.

2.9 DOCUMENTATION

2.9.1 Groundwater Sampling Record

Each sampling event for each monitoring well will be recorded on a separate Groundwater Sampling Record form. The documentation should include the following:

A. Project identification;

B. Location identification;

C. Sample identification(s) (including quality control samples);

D. Date and time of sampling;

E. Purging and sampling methods;

F. Sampling depth;

G. Name(s) of sample collector(s);

H. Inventory of sample bottles collected including sample preservation (if any), number, and types of sample bottles;

I. Total volume of water purged;

J. Results of field measurements and observations (time and cumulative purge volume, temperature, pH, specific conductance, turbidity, sediment, color, purge rate);

K. Equipment cleaning record;

L. Description and identification of field instruments and equipment; and

M. Equipment calibration record.

When the sampling activity is completed, the Groundwater Sampling Record will be checked by the MFG Project Manager or his/her designee, and the original record will be placed in the MFG project file.

2.9.2 Surface Water Sampling Record

Each sampling event for each surface water sampling station will be recorded on a separate Surface Water Sampling Record form (Figure SOP-12-2). The documentation should include the following:

A. Project identification;

B. Location identification (sampling station);

C. Sample identification(s) (including quality control samples);

D. Date and time of sampling;

E. Description of sampling location;

F. Sampling depth below water surface;

G. Sampling method;

H. Condition of water (standing or moving);

I. Description of flow measurement method, if applicable, and any flow data;

J. Instrument calibration and cleaning record;

K. Results of field measurements and observations (time, temperature, pH, specific conductance, turbidity, sediment, color);

L. Name(s) of sample collector(s); and

M. Sketch map showing location of sampling station and permanent landmarks.

When the sampling activity is completed, the Surface Water Sampling Record will be checked by the MFG Project Manager or his/her designee, and the original record will be placed in the MFG project file.

3.0 QUALITY CONTROL

3.1 Chain-of-Custody and Request for Analysis Form

A Chain-of-Custody and Request for Analysis form (CC/RA form) will be filled out as described in the MFG SOP entitled SAMPLE CUSTODY. Sample custody procedures are discussed and the CC/RA form presented in the MFG SOP entitled SAMPLE CUSTODY, PACKAGING AND SHIPMENT.

3.2 Equipment Cleaning

Sample bottles and bottle caps will be cleaned and prepared by the analytical laboratory or their supplier using standard EPA-approved protocols. Sample bottles and bottle caps will be protected from dust or other contamination between time of receipt by MFG and time of actual usage at the sampling site.

Groundwater sampling equipment may be dedicated to a particular well at a project site. Prior to installation of this equipment, all equipment surfaces that will be placed in the well or may come in contact with groundwater will be cleaned to prevent the introduction of contaminants (refer to the MFG SOP entitled EQUIPMENT DECONTAMINATION).

Sampling equipment that will be used at multiple wells or sampling locations will be cleaned after sampling at each location is completed in accordance with the MFG SOP entitled EQUIPMENT DECONTAMINATION.

Equipment such as submersible electric pumps, which cannot be disassembled for cleaning, will be cleaned by circulating a laboratory-grade, detergent and potable water solution through the assembly, followed by clean potable water from a municipal supply, and then by distilled or deionized water. Equipment cleaning methods will be recorded on the Groundwater Sampling Record and Surface Water Sampling Record.

3.3 Records Review

The MFG Project Manager or designated QA reviewer will check and verify that documentation has been completed and filed per this procedure.

MFG, Inc.

STANDARD OPERATING PROCEDURE No. 15

SURFACE WATER DISCHARGE MEASUREMENT

1.0 SCOPE AND APPLICABILITY

This Standard Operating Procedure (SOP) describes the protocol for collecting discharge measurements in streams and ditches. Discharge is defined as the volume rate of flow of water, including any substances suspended or dissolved in the water. Discharge will be expressed in cubic feet per second (cfs) or gallons per minute (gpm). This Standard Operating Procedure provides a method for describing a current and three methods for measuring discharge: 1) volumetric method, 2) area-velocity method, and 3) flume method. Note that the protocol for collection of surface water samples is included in the MFG SOP entitled WATER QUALITY SAMPLING.

The procedures presented herein are intended to be general in nature. As the work progresses, and if warranted, appropriate revisions may be made when approved in writing by the MFG Project Manager.

2.0 PROCEDURES

The selection of an appropriate method for discharge measurement depends on the flow conditions. In some conditions, the flow measurement methods described here may be impossible to implement (e.g., extreme high-flow conditions). If unmeasurable flow conditions are encountered, then field personnel will attempt to measure flow at a point upstream or downstream of the sample site. The field personnel will also note the conditions that inhibited more accurate measurement at the designated measurement location.

2.1 Current Description

In cases where a discharge measurement is not required but a description of the direction and relative rate of flow is useful, the following method for current measurement may be used.

The current within a moving body of water and its direction is variable by location and depth. Current measurement may be used to define the movement of water at a specified location and depth where a sample is collected. Qualitative measurement of current is made by using a strip of soft tape or cloth attached to the end of a pole. The strip will indicate the presence of water flow and direction of flow at the location and depth. The diameter of the pole should be sufficiently small to prevent directional error. Quantitative measurements may made using a current meter, which determines the water velocity (feet per second) from the revolution of an impeller or from pressure exerted by the water, or one of the other methods described in Section 2.2.

2.2 Discharge Measurement

The selection of discharge measurement method depends on streamflow rate and/or specific channel characteristics. For pipes, drain system outfalls and cases where flows are too small or stream gradients are too high, the volumetric method is appropriate. In cases where water depth is greater than 0.3 feet or the channel cross section is wide, discharge should be measured using the area-velocity method. Where flows are below the practical limit that can be measured with the area-velocity method, the flume method is best. Where the total discharge is conveyed through two channels or differing types, a combination of these methods may be appropriate.

2.3 Volumetric Method

The volumetric method is a simple and accurate method for measuring flow from small discharges such as gravity flow discharged from pipe outlets. This method involves observing the time required to fill or partly fill a calibrated container to a known volume. Alternatively, in the case of measuring discharge remotely in a sump or standpipe setting, the volumetric method may be performed by capturing flow in a container for a set period of time, no less than 10 seconds. This volume of water is then measured and discharge is determined.

2.3.1 Equipment

The volumetric method is particularly useful for the measurement of small flows. Equipment required to make this measurement is a calibrated container and a stopwatch. Calibrated containers of varying sizes include: 5-gallon bucket, 2-liter graduated cylinder, 1-liter graduated cylinder, 1-liter bucket, etc.

Extension rods will be used to hold a container for capturing flow in enclosed areas containing discharging pipes.

2.3.2 Maintenance and Calibration Procedures

Graduated cylinders are incremented in terms of milliliters and can be easily converted to gallons. The incremental volume of a 5-gallon bucket can be determined by adding known volumes of water and recording the depth after each addition.

2.3.3 Field Procedures

Upon arrival at the site, the field personnel will evaluate the flow conditions to select the appropriate method for flow measurement. If the flow conditions meet those outlined in Section 2.2.1, then field personnel will observe and use judgment in approximating the flow volume and will select an appropriately sized volumetric container to use the volumetric method of flow measurement.

A technician will use a stopwatch to measure the time required to fill a volumetric container. The technician will time flow into the container for a minimum of 10 seconds. Five consecutive measurements will be made and noted, and the results will be averaged to determine the discharge.

If remote measurement is necessary, a container will be attached to an extension rod. The technician will time flow for a minimum of 10 seconds. The volume of water will then be poured into a calibrated container, measured, and recorded. Five such measurements will be made, noted, and the results averaged to determine the discharge.

2.3.4 Discharge Calculations

Discharge will be determined initially in gallons per second (gal/s) or in milliliters per second (ml/s). These values will be noted, but the averaged value will be reported in cubic feet per second (cfs). Calculations will be performed as follows:

- Record each of the five measurements in terms of gallons per second or milliliters per second, depending on the volumetric container.
- If one of the five measurements is 50 percent or more different from the other measurements, then this value will not be used. Instead, five additional measurements will be taken and, provided that none of these measurements differs by greater than 50 percent from the other measurements, these values will be used.
- Average the five values.
- Leakage around the discharge pipe, if any, will also be estimated and noted.
- Convert the averaged value to cfs as follows:

- to convert ml/s to cfs, multiply by 3.53×10^{-5}
- to convert gal/s to cfs, multiply by 0.134

- Record discharge in cfs.

2.4 Velocity-Area Method

The vertical axis current meter may be used to perform velocity-area method discharge measurements. A common type of vertical axis current meter is the Price meter, type AA, Marsh-McBirney. A current meter is an instrument used to measure the velocity of flowing water. The principle of operation is based on the proportionality between the velocity of the water and the resulting angular velocity of the meter rotor. By placing a current meter at a point in a stream and counting the number of revolutions of the rotor during a measured interval of time, the velocity of water at that point is determined. The number of revolutions of the rotor is obtained by an electrical circuit through the contact chamber. Contact points in the chamber are designed to complete an electrical circuit at selected frequencies of revolution. The electrical impulse produces an audible click in a headphone. The intervals during which meter revolutions are counted are timed with a stopwatch.

A Price pygmy meter may be used in shallow depths and low-velocity waters. The pygmy meter is scaled two-fifths as large as the type AA meter. The pygmy meter makes one contact (click) per revolution and the type AA meter can make one click per revolution or one click per five revolutions. The Marsh-McBirney type meter can be used at any depth greater than 0.15 feet.

2.4.1 Introduction

The current meter measures velocity at a point. The velocity-area method requires measurement of the mean velocity in selected subsections of the stream cross-section. By dividing the stream width into subsections, discharge becomes the total of discharges measured in each subsection. Velocity

(V) is measured at each subsection, and discharge becomes the sum of the products of each velocity point and the cross-sectional area of each subsection:

$$Q = \sum(A_i * V_i)$$

where: Q = Streamflow in cfs,
A = Area of stream subsection in square feet, and
V = velocity in feet per second.

A cross section is defined by the depths at vertical points (i = 1, 2, 3, ...n) where the average velocity is measured.

In general, the person(s) measuring discharge should strive to measure no more than 5 percent of the flow in any one subsection. However, for small streams this is often impossible. Therefore, the person(s) should divide the channel cross-section into as many subsections as possible and make two complete discharge measurements using different sections for each. Subsections do not need to be identical in width. Velocities near banks are generally lower than velocities near the center of streams; therefore, these subsections may be wider than subsections near the center. Subsections will also be more closely spaced if a stream has an unusually deep portion in the cross-section.

Typically, velocities will be measured by current meter for a 40- to 70-second period. It is recognized that 40 to 70 seconds is not long enough to ensure the accuracy of a single-point observation of velocity. However, because pulsations caused by turbulent and eddying effects are random and because velocity observations during a discharge measurement are made at several verticals, there is little likelihood that the pulsations will bias the total measure discharge of a stream.

2.4.2 Required Measurement Conditions

To make an area-velocity discharge measurement, the following conditions are required:

1. The stream must be channelized.

2. Depth must be greater than 0.2 foot across most of the cross-section being measured.

The ideal channel cross-section is trapezoidal in shape, completely smooth in boundary materials, and possesses a uniform velocity distribution. Such an ideal condition is rarely observed. Therefore, minor modifications to the stream channels will be used to optimize measurement conditions. These modifications may include removal of aquatic vegetation, ice, and moving small stones that impact velocity upstream or downstream of the cross-section.

If flow conditions permit, current meter measurements will be made by wading. The type AA or pygmy meter is used for wading measurements. The table below lists the type of meter and velocity method to be used for wading measurements at various depths. The persons(s) should stand at arm's length to the side of the meter.

Velocity Measurement Point Selection

Stream Depth (ft)	Type of Meter	Velocity Measuring Point(s) (% of Depth)
2.5 or more	Type AA/Marsh-McBirney	0.2 and 0.8
1.5 - 2.5	Optional/Marsh-McBirney	0.6
0.3 - 1.5	Optional/Marsh-McBirney	0.6
< 0.3	Pygmy	0.5

Some departure from these specifications will be permitted. A Marsh-McBirney meter is appropriate for all depths deeper than 0.15 feet. Do not switch from one meter to another in the middle of a discharge measurement.

Under open channel laminar flow conditions, the effect of fluid contact with the bed of a stream channel and the air is a vertical distribution of velocities. Consistent with this velocity distribution, actual observation and mathematical theory has demonstrated that a single measurement of velocity taken at 0.6-depth or the average of two point velocities taken at 0.2 and 0.8 of the depth below the surface accurately results in mean velocity in the vertical (U.S.G.S. Water-Supply Paper 2175, 133-134 pp).

If the stream is generally less than 2.5 feet deep, the six-tenths (0.6) method will be used. If the stream is generally greater than 2.5 feet, the two- and eight-tenths (0.2 and 0.8) method, also known as the two-point method, will be used. A complete discussion concerning how to set the wading rod to place the current meter at proper depths is contained in Section 2.3.5, Field Procedures.

In the 0.6-depth method, an observation of velocity made in the vertical at 0.6 of the depth below the surface is used as the mean velocity in the vertical. In the two-point method of measuring velocities, observations are made in each vertical at 0.2 and 0.8 of the depth below the surface. The average of the two observations is taken as the mean velocity in the vertical.

A depth of 1.25 feet will accommodate the 0.6-depth method without causing the meter to be set closer than 0.5 feet from the stream bed; if the meter is set any closer to the stream bed, it will under-register the velocity. If the technician is at a measurement section that has only a few verticals shallower than 1.25 feet, the technician should use the type AA meter rather than the pygmy meter.

Vertical axis current meters do not register velocities accurately when placed close to a vertical wall. A Price meter held close to a right-bank vertical wall will under-register because the slower water velocity near the wall strikes the effective (concave) face of the cups. The converse is true at a left-bank vertical wall. (The terms "left bank" and "right bank" designate direction from the center of a stream for an observer facing downstream.) The Price meter also under-registers when positioned close to the water surface or close to the stream bed.

2.4.3 Equipment

Current meters, timers, depth and width measuring devices, and a means of counting meter revolutions are needed for measurement of discharge. The equipment includes:

- Top-setting wading rod and current meter;
- Width-measuring devices, either engineer's tape or tagline;
- Digital counter or headset and stopwatch;
- Current meter rating tables;
- Stakes for width-measuring devices; and
- Calculator.

Top-Setting Wading Rod. The depth-measuring device that will be used is the wading rod. The current meter is attached to the wading rod. The top-setting wading rod has a 2-inch hexagonal main rod for measuring depth and a d-inch diameter round rod for setting the position of the current meter.

Current Meter. Vertical axis current meter, Marsh-McBirney, type AA meter, or pygmy meter.

Engineer's Tape or Tagline. Tape measures or premarked taglines are used for stream width measurements. Orientation normal to the flow patterns of the stream and elimination of most of the sag, through support or tension, are recommended for improved accuracy.

Digital Revolution Counter or Headset. The digital revolution counter attaches to an electronic connection at the top of the wading rod. The digital display shows the number of seconds of elapsed time. The person(s) stops the counter after 40 or more seconds, and the counter automatically displays the velocity.

If the digital counters are unavailable, the headset will be used as a means for determining the number of revolutions. A headset attaches to an electronic connection at the upper end of the wading rod.

The person(s) wears this headset to listen to the audible clicking sounds produced by current meter revolutions. The number of rotations are counted and timed. Velocities as a function of time are listed on a current meter rating chart, which is kept in the current-meter carrying case.

Stopwatch. A stopwatch is used to measure time during which velocity is measured at each point in the cross-section.

2.4.4 Maintenance and Calibration Procedures

Prior to and following the use of the current meter, spin tests will be conducted to ensure that the unit performs acceptably. The spin test will be performed in an enclosed area, such as in the cab or in the enclosed rear of the trunk, to prevent wind interference. The test is to be performed prior to attaching the current meter to the wading rod. While holding the meter steady in an area sheltered from breezes, the technicians will spin the rotor and then press the start button on the stopwatch. The technician will observe the meter until the rotor ceases to spin.

The duration of the spin for the pygmy meter will be more than 40 seconds, and for the Price AA meter, it will be more than 90 seconds. If the meter fails to meet the time-of-spin criteria, the meter will be cleaned and oiled before use. If the meter continues to spin well beyond these time limits, the record will indicate that the meter spun for 40+ seconds in the case of the pygmy meter, or for 90+ seconds in the case of the Price AA meter.

To ensure reliable observations of velocity, it is necessary that the current meter be kept in good condition. Before and after each discharge measurement, the meter cups or vanes, pivot and bearing, and shaft will be examined for damage, wear, or faulty alignment. During measurements, the meter will be observed periodically when it is out of the water to be sure that the rotor spins freely.

Meters will be cleaned and oiled daily when in use. If measurements are made in sediment-laden water, the meter will be cleaned immediately after each measurement. After oiling, wipe away any excess oil and spin the rotor to ensure that it operates freely. If the rotor stops abruptly, the cause of the trouble will be determined and corrected before using the meter.

In addition to meter maintenance, the entire unit consisting of current meter, wading rod, and digital counter or headset will be checked before departure to the field each day as follows:

- Attach the current meter and digital counter/headset to the wading rod.
- Check the digital counter by ensuring that the readout is visible when the unit is turned on.
- If a headset is being used:
    - Spin the current meter to ensure that audible clicks occur.
    - If audible clicks do not occur, the following steps should be taken:
        - Check that electronic connections are tight.
        - Check that the cat's whisker lightly contacts the upper part of the shaft.
        - Spin again. If audible clicks still do not occur, check that the battery in the headset is properly aligned. Replace the battery, if necessary.

2.4.5 Field Procedures

Upon arrival at the site, the field technicians will evaluate the flow conditions to determine which measurement method is appropriate. Based on flow conditions, either the Price AA meter or the pygmy meter will be selected to perform an area-velocity measurement.

At each measurement point (or section) across the stream cross-section, depth is measured prior to measurement of velocity. Place the wading rod about 0.5 feet downstream from the tagline. Place the wading rod in the stream so the base plate rests on the stream bed. The depth of water is read from the graduated main rod. The main rod is graduated into 0.1-foot increments. These increments are indicated by a single score in the metal. Half-foot increments are marked by two scores in the metal, and each foot is marked by three scores in the metal. A vernier scale on the upper handle of the rod corresponds to 0.1-foot increments, and has 1 through 9 in raised numbers next to raised marks. A sliding, adjustable rod, known as the setting rod, to which the meter is attached, has single scored marks that are aligned with values on the vernier scale.

In high-velocity areas, it is recommended that depth be read as the value between depth on the upstream side of the rod and depth on the downstream side of the rod. Depth is measured to the nearest 0.2 foot. This depth is used to set the vertical location of the current meter.

The setting rod is then adjusted downward so that the scored mark of the setting rod that corresponds to the range of depth in feet (e.g., if depth = 0.46, range in feet = 0; or if depth = 1.72, range in feet = 1) is aligned with the stream depth value transposed to the vernier scale. This automatically positions the meter for use in the 0.6 method as the meter is then six-tenths of the total depth from the surface of the water.

For using the two-point method of velocity measurement, the depth of water is divided by 2. This value is set so that the meter will be at the 0.8-depth position from the water surface. The depth of water is then multiplied by 2, and this value is set. The meter will then be at the 0.2-depth position measured down from the water surface. These two positions represent the conventional 0.2- and 0.8-depth positions. If depths are less than 0.30 foot, the 0.5 method may be used. The observation depth recorded will then be 0.5 of the total depth.

If water quality or sediments are sampled in conjunction with discharge measurement, samples will be collected prior to making discharge measurements. The following steps are to be followed in discharge measurement:

- Evaluate the measurement location. Choose a location where flow is least turbulent. If the prescribed location is in a stream reach with highly turbulent flow conditions, try to select a location immediately upstream or downstream. Flow should be visible from bank to bank. Eddies and slack water must not be present. Neither the type AA meter nor the pygmy meter will be used for measuring velocities slower than 0.1 fps unless absolutely necessary.

- Remove aquatic vegetation, ice, or other minor flow impediments. When such modifications are made, exercise great care to avoid unnecessary movement of sediments allow flow to stabilize before the current meter measurement begins.

- Position a tape about 1 foot above the surface of the water. Secure the tape so that it remains taut and perpendicular to the channel.

- Select a starting point at either the left bank (left edge of water, LEW) or the right bank (right edge of water, REW). LEW and REW are determined when facing downstream.

- Note the distance in feet, and the stream direction, that this cross-section lies from the prescribed location. For example, the note may read "25 feet downstream" or "15 feet upstream."

- Measure the width of the stream. After selecting the Price AA or pygmy meter, select the number of subsections in which to measure velocity attempting to measure no more than 10 percent of the total flow in any one section, if possible.

- After determining the distance desired between measuring points, commonly referred to as sections, measurement can begin. Record the time and bank at which measurements start on the discharge measurement notes as "REW Start 0000", using REW or LEW depending upon whether starting at the right or the left edge of the water.

- Note the distance to the beginning edge of water from the initial point. The initial point is an arbitrary point on the tape, preferably zero, which lies on the shoreside of the stream. All station locations are recorded as distances from the initial point.

- Proceed to the first station beyond the edge of water. Record the distance from the initial point on the discharge measurement notes. Place the wading rod into the stream so the base plate rests on the stream bed.

- Stand downstream of the tagline or tape and face upstream. Do not stand behind or close to the meter. Raise the current meter on the wading rod so that it is well above the surface of the water.

- Measure stream depth at the measurement point as indicated on the wading rod. Record the stream depth to the nearest 0.2 foot (for example 0.32 feet or 1.54 feet).

- Lower the meter to the required depth and record the observation depth. The observation depth as a fraction of total depth is 0.6, 0.2, 0.8 or occasionally 0.5.

- The technician will stand in a position that least affects the velocity of the water passing the current meter. That position is usually obtained by facing upstream with the arm fully extended. The technician will stand at about a 45-degree angle downstream from the wading rod. The wading rod is held in a vertical position with the meter parallel to the direction of flow. Avoid standing in the water when possible.

- Start the digital counter. After 40 seconds, stop the counter. Note that the counter reports velocity.

- If using the headset rather than the digital counter, start the stopwatch on the first click and begin counting clicks. The first click counted after starting the stopwatch is counted as one.

- After at least 40 seconds have passed, stop the stopwatch on a click. Record the number of seconds and the number of revolutions (clicks) on the same line of the notes as the recorded depth.

- Determine velocity as a function of elapsed time and number of revolutions from the velocity chart. Record velocity in the appropriate column. If the flow meter is not lined up parallel to the flow, the cosine of the angle that the flow direction is from parallel is needed to correct velocity values. This is done by the following:

  - Hold up a copy of the discharge notes.

  - Line up the dot (shown in the cosine of the angle column of the notes) with the number on the tape that designates the measurement point of the cross-section.

  - Rotate the note by pivoting at the dot until the edge of the note is aligned with the flow. Find the number along the note's perimeter that lines up with the tape. This is the cosine of the angle. Record this value for the station.

- Proceed to the next station. Record the distance form the initial point to the station. Repeat measurements of depth and velocity. Continue in this manner across the stream.

- After recording the distance measurement at the last station, record the time at which the ending edge of water is reached (e.g., LEW [or REW] FINISH 1330).

- Note velocity and depth at the edge of water as zero.

- Evaluate and record flow characteristics, weather conditions, air temperature, water temperature, observer(s), type of meter, and remarks.

- If less than 20 subsections have been used for the measurement, repeat the measurement steps. Begin from the opposite bank from where the previous measurement began.

2.4.6 Discharge Calculations

Calculate discharge on the discharge notes as follows:

- Use the distances form initial point to compute width for each subsection. The first width is computed by subtracting the first distance (edge of water) form the second distance and dividing this quantity by two. The second width will be the difference between the third distance and the first distance divided by two. For each subsequent width, subtract the previous station distance from the following station distance and divide this quantity by two. The final width is calculated as the difference between the final distance and the second-to-last distance divided by two. Sum the width column and check to ensure that the calculated width equals the distance between the REW and LEW.

- Multiply the width by the depth for each station to determine the area of each subsection. Sum the areas to determine total area.

- If the angle between the flow and the meter orientation is not 90 degrees, correct he measured velocity readings by multiplying the velocity by the cosine of the angle.

- Multiply the velocity by the area for each station to obtain the discharge for each subsection.

- Sum the discharges for each subsection to determine total discharge and record the value.

- If two sets of discharge measurements beginning at opposite banks were taken, repeat the discharge calculations for the second set of data. Average the total discharges for the two measurements. Record the average value and report it for input into the database.

2.5 Control Structures

Control structure such as flumes can be used to determine discharge. These structures have regular dimensions that allow for a consistent relationship between water level and discharge. This section describes use of Parshall flumes to measure discharge.

2.5.1 Introduction

A calibrated constriction placed in a stream channel changes the level of the water in or near the constriction. Flumes are constructed so that a restriction in the channel causes the water to accelerate, producing a corresponding change (drop) in the water level. When the physical dimensions of the flume constriction are known, discharge through constriction may be determined from measurement of depth. See below for a description of discharge measurement for Parshall flumes.

Typical flumes consist of three sections:

- A converging section to accelerate the approaching flow.
- A throat section, whose width is used to designate flume size.
- A diverging section, designed to ensure that the level downstream is lower than the level in the converging section.

The stage of a stream is the height of the water surface above an established elevation. Stage is usually expressed in feet. The Parshall flume consists of a converging section with a level floor, a throat section with a downward sloping floor, and a diverging section with an upward sloping floor. The principal feature of the Parshall flume (developed by R. Parshall in 1922) is an approach reach having converging sidewalls and a level floor, the downstream end of which is a critical depth cross-section. The primary stage measurement is made in the approach reach at some standard distance upstream from the critical-depth cross-section.

The flumes are designated by the width (w) of the throat. Flumes having throat widths from 3 inches (in.) to 8 feet (ft.) have a rounded entrance whose floor slope is 25 percent. Smaller and larger flumes do not have that feature.

2.5.2 Required Measurement Conditions

Ideally, flow rate through a flume may be determined by measurements at a single point some distance downstream from the inlet and above the throat.

2.5.3 Equipment

The following equipment will be needed:

- Current meter;
- Carpenter's level;
- Framing square;
- Measuring tapes; and
- Staff gauge.

2.5.4 Maintenance and Calibration Procedures

All flumes will be inspected to determine that entrance conditions provide a uniform influent flow distribution, the converging throat section is level, and that the throat section walls are vertical. The flume will be closely examined to determine that it is discharging freely. Any problems observed during the inspection will be noted and reported to the field manager.

2.5.5 Procedures

Steps to be followed in measuring discharge.

- Remove any material that may have accumulated in the flume or on the weir;
- If the station includes a chart recorder, inspect the strip chart on the recorder to verify that it is operating;
- Note any deterioration of the station; report these conditions to the field manager at the conclusion of daily data collection activities;
- Measure and record the throat width (W) to the nearest 1/10 of an inch;
- Use the staff gauge to measure and record the gauge height (H) to the nearest 0.2 foot;
- Calculate discharge as described in Subsection 2.5.6; and
- Record the calculated discharge and the time and date of the site visit.

2.5.6 Discharge Calculations

A set of flume tables is necessary for calculating flows. The flume tables are specific to the type of flume. For Parshall flumes, refer to Free-Flow Discharge-Parshall Flume (cfs) (attached). Based on the gage height (head, H, in feet) and the throat width of the flume (size of flume, W), the discharge is read directly from the table. Note that the approximate values of discharge for heads other than those shown may be found by direct interpolation in the table.

2.6 Documentation

Information required by this SOP will be documented in detail in a bound field notebook. This information includes the calibration data for flow measurement devices and field discharge measurement data.

Documentation will also include the type of flow measurement device, including a model number and instrument serial number; a detailed description of measurement location and weather conditions during the measurement; and calculations.

3.0 QUALITY ASSURANCE/QUALITY CONTROL

3.1 Calculation Check

All calculations will be reviewed for accuracy and conformance with these procedures. The calculation review will be performed by a technically qualified individual before results are reported or interpreted. The calculation check shall be documented by the reviewer's initials and date of review. A copy of the reviewed calculations should be included in the project file.

3.2 Records Review and Management

The project manager or designated QA reviewer will verify that documentation has been completed and filed per this procedure.

4.0 REFERENCES

The following list of references was reviewed prior to compiling this procedure:

Rantz, S.E. et al., 1982. *Measurement and Computation of Streamflow: Volume 1, Measurement of Stage and Discharge*, U.S. Geological Survey Water Supply Paper 2175. U.S. Government Printing Office, Washington, D.C.

U.S. Department of the Interior, 1977. *National Handbook of Recommended Methods for Water-Data Acquisition.* Office of Water Data Coordination, U.S. Geological Survey, Reston, VA.

U.S. Environmental Protection Agency, 1986. *Engineering Support Branch Standard Operating Procedures and Quality Assurance Manual.* Environmental Services Division, Region IV, Athens, GA.